LANSCE DIVISION RESEARCH REVIEW

Overview of Proton Radiography Experiments at LANSCE

F. Merrill, C. Morris (P Division), Proton Radiography Team

The proton radiography (pRad) program at the Los Alamos Neutron Science Center (LANSCE) is investigating weapons-physics issues related to the physics of implosions, hydrodynamics, high explosives (HE), and the dynamic failure properties of materials when explosively driven by HE. pRad provides the unique capability of studying the evolution of explosive processes with high spatial and temporal resolution. With this technique, 800-MeV protons, provided by the LANSCE linear accelerator, penetrate directly through an exploding or imploding system. The protons, delivered in 50- to 100-ns-long pulses, interact with the material of the dynamic system and undergo scattering that is proportional to the product of the density and thickness of the material. The configuration of the materials, which are moving with typical velocities of ~ 1 mm/μs, is effectively "frozen" during the short duration of the proton pulses. These protons are then transported from the object, through a magnetic lens to a Fourier point where protons are intercepted if they were scattered to angles larger than some maximum cutoff. This cutoff angle provides the image contrast, whereby the proton density is lowered for protons passing through thicker materials. The protons surviving the cutoff angle are then magnetically transported to a scintillator located at an image location, where the proton positions are identical to their initial position at the object location. The scintillator converts the proton flux to light, which is collected by a series of fast-gated cameras. The multiple images are separated in time by typically 1 μs for up to 21 pulses per dynamic event and can be combined to produce a "motion-picture" of the dynamic event in which materials travel ~ 1 mm between frames.

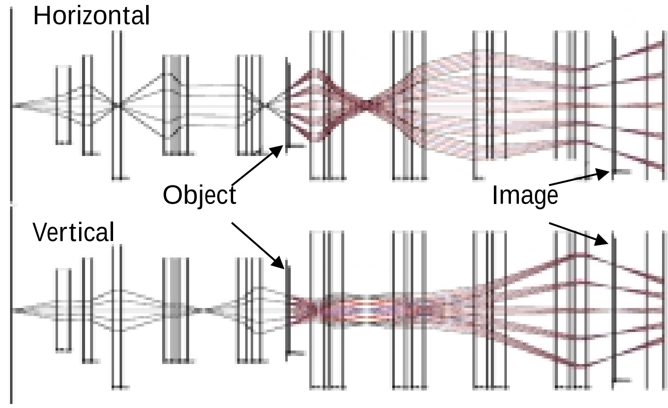
pRad Experiments at LANSCE

In 2001, 36 dynamic pRad experiments were performed at LANSCE in support of the weapons-physics efforts at Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), Lawrence Livermore National Laboratory (LLNL), and the Aldermaston Weapons Establishment (AWE), bringing the total number of dynamic experiments performed at LANSCE to 114. For these shots, the LANSCE accelerator and beam-delivery complex provided protons with 100% reliability. In addition to these dynamic experiments, beam time was used for detector and concept development and for the radiography of static mockups to determine shot configurations and the design of future experiments. The 36 pRad shots in 2001 fell into three categories: (1) outside-user experiments, (2) HE-driven dynamic studies, and (3) implosion dynamic studies. For outside-user experiments, we hosted SNL for five shots to continue investigations on explosively driven voltage bars, and LLNL for seven dynamic experiments (Fig. 1). HE dynamic shots included further investigations of the formation of dead zones in HE, detonation-wave shapers, and detonation-wave colliders, where two independent detonation waves within the same sample of HE are run against each other. Experiments were also performed to study material dynamics and failure mechanisms (such as spall formation) and to obtain sheet-jet uniformity measurements and ejecta measurements.

↑ ***Fig. 1.*** *Installation of a dynamic HE experiment in the 6-ft containment vessel in Area C.*

A third in a series of BilliG experiments (BilliG5L) was performed at LANSCE on September 7, 2001, in collaboration with AWE. This experiment required the joint efforts of LANSCE, P, X, ESA, ESH, and DX Division personnel. The chief scientific goals of the experiment were to study implosion-related phenomena relevant to the performance of nuclear weapons and to further validate the capabilities of proton beams for radiographic imaging of nuclear-weapons hydrodynamic tests. The results of a Laboratory-Directed Research and Development (LDRD) effort to study dynamic systems at the meso-scale level were used to develop a magnifier system deployed for this BilliG5L shot. This optical magnification provided improved resolution along with a wider dynamic range, resulting in higher-quality radiographs of the imploding system.

The LDRD-sponsored effort to extend pRad capabilities to study dynamic systems with finer resolution also produced the first magnetically magnified dynamic radiographs. In this system, the protons are allowed to expand by a factor of 3.1 by the magnetic lattice while still being in focus. A diagram of the proton trajectories through this system is shown in Fig. 2. This system results in factor of 3 magnification of the radiographic image at the scintillator. This magnifying system was used to measure the velocity of markers (i.e., embedded gold beads) in shocked materials for SNL and to measure detailed burn-front characteristics in HE by X-5 at LANL.



↑ ***Fig. 2.*** *Magnifier setup for three-fold magnetic magnification. The colored trajectories correspond with proton trajectories passing through the radiography system. The trajectories at the image location have been allowed to expand by a factor of 3 while maintaining the focus.*

In addition, a nine-frame framing camera, developed by Bechtel-Nevada, was installed and commissioned in the LANSCE pRad Facility in Area C. This camera, in combination with the 12 single-shot cameras, collected 21 images of the evolving copper sheet jet, which was the last dynamic pRad experiment of 2001. This number of images is a pRad record and sets a new standard in "motion-pictures" for future dynamic experiments at LANSCE.

For more information, contact Frank Merrill (P Division), (505) 665-6416, MS H846, fmerrill@lanl.gov.

Produced by the LANSCE-4 communications team: Sue Harper, Grace Hollen, Barbara Maes, Sharon Mikkelson, and Garth Tietjen.

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LANSCE Los Alamos Neutron Science Center

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